



GEOLOGIC RESOURCE MONITORING PARAMETERS

Soil Quality



Brief Description: Soils vary greatly in time and space. Over time-scales relevant to geoindicators, they have both stable characteristics (e.g. mineralogical composition and relative proportions of sand, silt and clay) and those that respond rapidly to changing environmental conditions (e.g. ground freezing). The latter characteristics include soil moisture and soil microbiota (e.g. nematodes, microbes), which are essential to fluxes of plant nutrients and greenhouse gases. The soils of boreal regions are estimated to hold the equivalent of some 60% of the current atmospheric carbon: long-term warming is expected to increase decomposition and drying, thus potentially releasing huge volumes of methane and CO₂. Recent research shows that the Alaskan tundra no longer serves as a carbon sink, but has begun to release significant quantities of carbon.

Most soils resist short-term climate change, but some may undergo irreversible change such as lateritic hardening and densification, podsolization, or large-scale erosion. Soil properties and climatic variables such as mean annual rainfall and temperature can be related by mathematical functions known as climofunctions.

Chemical degradation takes place because of depletion of soluble elements through rainwater leaching, overcropping and overgrazing, or because of the accumulation of salts precipitated from rising groundwater or irrigation schemes. It may also be caused by sewage containing toxic metals, precipitation of acidic and other airborne contaminants, as well as by persistent use of fertilizers and pesticides. A widespread problem is the retention in the soil organic matter and clay minerals of potentially toxic metals and radionuclides (e.g. Cu, Hg, Pb, Zn, ²²⁶Ra, ²³⁸U). These and other chemical components may be catastrophically released as what are commonly referred to as 'chemical time bombs' where the pH of the soil is decreased by acidification or where other environmental disturbances (e.g. erosion, drought, land use change) intervene. Soils also act as a primary barrier against the migration of organic contaminants into groundwater. Key indicators are pH, organic matter content, sodium absorption ratio, cation exchange capacity, and cation saturation.

Physical degradation results from land clearing, erosion and compaction by machinery. Soil structure may be altered so that infiltration capacity and porosity are decreased, and bulk density and resistance to root penetration are increased. Such soils have impeded drainage and are quickly saturated: the resultant runoff can cause accelerated erosion and transport of pollutants such as pesticides [see soil and sediment erosion]. The key soil indicators are texture (especially clay content), bulk density, aggregate stability and size distribution, and water-holding capacity.

Significance: As one of Earth's most vital ecosystems, soil is essential for the continued existence of life on the planet. As sources, stores, and transformers of plant nutrients, soils have a major influence on terrestrial ecosystems. Soils continuously recycle plant and animal remains, and they are major support systems for human life, determining the agricultural production capacity of the land. Soils buffer and filter pollutants, they store moisture and nutrients, and they are important sources and sinks for CO₂, methane and nitrous oxides. Soils are a key system for the hydrological cycle [see groundwater chemistry in the unsaturated zone]. Soils also provide an archive of past climatic conditions and human influences.

Environment where Applicable: Any land surface, especially agricultural and afforested areas.

Types of Monitoring Sites: Undisturbed lands, such as uncultivated grasslands and forests, can provide reference sites for comparison with changes in soils subject to human activities related to forestry, agriculture and urbanization.

Method of Measurement: Routine physical, chemical and morphological descriptions. Chemical degradation can also be monitored by analysis of groundwater [see groundwater quality].

Frequency of Measurement: Every 1-10 years

Limitations of Data And Monitoring: Soils can vary considerably in chemical, physical and biological properties, both vertically through the soil profile, and horizontally, so that it may be difficult to select representative sites for monitoring.

Possible Thresholds: Threshold values for chemical and physical degradation vary according to the usage of soils for agricultural, forestry, waste disposal, and other purposes.

Key References:

Acton, D.F. & L.J.Gregorich (eds.) 1995. The health of our soils - toward sustainable agriculture in Canada. Centre for Land and Biological Resources Research, Ottawa: Agriculture and Agri-Food Canada.

Batjes, N.H. & E.M.Bridges 1992. A review of soil factors and processes that control fluxes of heat, moisture and greenhouse gases. Technical paper 23, Wageningen: International Soil Reference and Information Center.

Klute, A. (ed) 1986. Physical and mineralogical methods. Methods of soil analysis: Part 1. American Soil Science Society Agronomy Monograph 9.

Page, A.L., R.H.Miller & D.R.Keeney 1986. Chemical and microbiological properties. Methods of soil analysis: Part 2. American Soil Science Society Agronomy Monograph 9.

Peirce, F.J. & W.E.Larson 1996. Quantifying indicators for soil quality. In Berger, A.R. & W.J.Iams (eds). Geoindicators: Assessing rapid environmental changes in earth systems:309-321. Rotterdam: A.A. Balkema.

Ringrose-Voase, A.J. & G.S.Humphrey (eds) 1994. Soil micromorphology: studies in management and genesis. Amsterdam: Elsevier.

Related Environmental and Geological Issues: Accelerated contamination of groundwater can occur if the sorption capacity of soils for potentially toxic chemicals is exceeded by elevated levels from human activities. There is an extensive body of knowledge dealing with physical and chemical changes in soils under cultivation.

Overall Assessment: Soil quality is a sensitive indicator of natural and human-induced perturbations of the environment: changes may affect the quality of surface and groundwater. Monitoring changes in soil properties can assist in predicting the future value of soils for agricultural, forestry and other purposes.

Source: This summary of monitoring parameters has been adapted from the Geoindicator Checklist developed by the International Union of Geological Sciences through its Commission on Geological Sciences for Environmental Planning. Geoindicators include 27 earth system processes and phenomena that are liable to change in less than a century in magnitude, direction, or rate to an extent that may be significant for environmental sustainability and ecological health. Geoindicators were developed as tools to assist in integrated assessments of natural environments and ecosystems, as well as for state-of-the-environment reporting. Some general references useful for many geoindicators are listed here:

Berger, A.R. & W.J.Iams (eds.) 1996. Geoindicators: assessing rapid environmental change in earth systems. Rotterdam: Balkema. The scientific and policy background to geoindicators, including the first formal publication of the geoindicator checklist.

Goudie, A. 1990. Geomorphological techniques. Second Edition. London: Allen & Unwin. A comprehensive review of techniques that have been employed in studies of drainage basins, rivers, hillslopes, glaciers and other landforms.

Gregory, K.J. & D.E.Walling (eds) 1987. Human activity and environmental processes. New York: John Wiley. Precipitation; hydrological, coastal and ocean processes; lacustrine systems; slopes and weathering; river channels; permafrost; land subsidence; soil profiles, erosion and conservation; impacts on vegetation and animals; desertification.

Nuhfer, E.B., R.J.Proctor & P.H.Moser 1993. The citizens' guide to geologic hazards. American Institute for Professional Geologists (7828 Vance Drive, Ste 103, Arvada CO 80003, USA). A very useful summary of a wide range of natural hazards.